Potential for Increasing Nutrional Value of Sweet Potatoes

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NUTRITIONAL ANALYSIS OF SWEET POTATOES

Sweet potato is undeniably one of the world's most important food crops. Its main importance as food has been the carbohydrate content or starch source as a dietary staple. However, sweet potato can also be a source of other nutritionally important dietary factors. The nutritional composition of sweet potatoes has been reported by Watt (1963), Edmond and Ammerman (1971) and by a new report prepared by the S-101 Regional Technical Research Committee (1980). Efforts to increase consumption of sweet potatoes must go hand in hand with efforts to educate consumers on nutritional benefits of eating sweet potatoes. A short discussion of the major nutritional components of the sweet potato follows.

Vitamins

Vitamin A: Sweet potatoes are an excellent source of provitamin A (carotene) which is converted into vitamin A (retinol) by the body (Table 1). Many factors affect the level of carotene in sweet potatoes but the varieties now being grown in the United States can easily supply the recommended dietary allowance (RDA) of this vitamin.

Vitamin B complex: A 113 g serving of sweet potatoes can supply 2-6% of the recommended dietary allowance of niacin, 3-5% of the riboflavin requirement and 1-7% of the thiamine requirement. The main source of these vitamins is usually meat or meat products. There seems to be little variation in concentrations of vitamins from the B complex in sweet potatoes; the range of those tested is extremely narrow.

Vitamin C (ascorbic acid): Sweet potatoes currently being grown differ in ascorbic acid content with cooking method. They can supply between 25% and 50% of the recommended dietary allowance of vitamin C depending on whether the roots are canned or baked (S-101 Technical Committee 1980).

Carbohydrates and energy

The major energy supply to the human body is carbohydrates. Most of the current sweet potato varieties grown in the United States contain 25-30% carbohydrates in the roots and approximately 98% of those carbohydrates are easily digestible. Vines are much lower in carbohydrate content. The tremendous yielding capacity of sweet potatoes (up to 85 t/ha in experimental plots according to Collins in 1980) makes it an important carbohydrate source for areas where populations depend mostly on carbohydrates for their food source. A 113 g serving of sweet potatoes per day can supply 5% of the enerby requirements for a 23-50-year-old male.

Table 1. Nutritional	analysis of	canned	sweet	potatoes	(variety	Jewel)
	Root conten	t	PUV _S	% RD	A supplie	d

	Root content	RDA	% RDA supplied in 113 g sample
	(%)	<u>(a)</u>	
Solids	28.7		
Fats	0.3		
Protein	1.2	56	2.1
Carbohydrates	26.7		
Ash	0.5		
	(mg/100g)	<u>(mg)</u>	·
Calcium	11	800	1.6
Iron	0.9	10	10.4
Sodium	20 ^y	1000	2.3
Potassium	192 ^y	2000	10.8
Thiamin	0.02	1.4	1.4
Riboflavin	0.03	1.6	1.9
Niacin	0.3	18	1.7
Vitamin C	10	45	25
	IU ^x /100g	<u>IU</u>	
Vitamin A	5345	5000	121

xInternational units

Minerals

The major inorganic elements necessary for body processes are sodium, potassium, calcium and iron. The recommended dietary allowances for calcium. iron, sodium, and potassium are 800, 10, 1000, and 2000 mg/day respectively.

A 113 g sample will supply 1.6% of the calcium RDA and 10.2% of the iron RDA (S-101 Technical Committee 1980). It will also supply 2.3% of the sodium and 10.8% of the potassium RDA (Lopez et al 1980).

Protein

The recommended dietary allowance for protein is 56 g for a 23-50-yearold-male. A 113 g serving of sweet potato roots can provide 3-4% of the RDA (S-101 Technical Committee 1980).

POTENTIAL FOR INCREASING NUTRITIONAL COMPONENTS IN SWEET POTATOES

Efforts to increase nutritional components in sweet potatoes can be limited to specific areas which show greatest promise for a significant increase. Sweet potato is already recognized as an important source of carbohydrates in many areas of the world. The total production of carbohydrates is directly linked to yield. Average yield in the United States in 1980 was 12 t/ha with a high of 18.5 t/ha. In experimental plots we regularly obtain selections with total yield well over 56 t/ha. In many areas where a carbo-

 $[\]frac{z}{y}$ Recommended dietary allowance $\frac{y}{y}$ From Lopez, Williams and Cooler (1980)

hydrate source can be exploited for human consumption and where yields are low, breeding and cultural efforts should be directed toward increasing yields.

Mineral content of sweet potatoes is very low in terms of the percentage of the RDA supplied by eating a 140-170 g serving. Sweet potato breeding efforts are unlikely to increase significantly the levels of calcium. However, there does appear to be a possibility that levels of iron and/or potassium might be significantly increased provided high-iron and high-potassium germplasm can be located. In those genotypes tested, there appears to be little variation from genotype to genotype but a large root-to-root withingenotype variation. At present, data are not extensive enough to predict results of efforts to increase iron and potassium levels.

Sweet potatoes are an excellent source of provitamin A. Since high-carotene types favored mostly in the Western Hemisphere were induced to bloom and set seed, the carotene content in the popular types has risen from 6.2 mg/100g to 17.4 mg/100g (Miller and Hernandez 1970). Since high-carotene germplasm is easily available and present in high levels in all breeding programs in the United States, this character does not appear to be a critical nutritional character at this time from a breeding standpoint. The problem associated with high-carotene types of sweet potatoes is personal preference of many populations for the low-carotene or non-carotene types. Overcoming this preference in situations in which this carotene source is needed will require an extensive educational effort.

Most vitamins in the B complex in sweet potatoes appear to be present in concentrations which vary little from genotype to genotype. The range of values reported is extremely narrow. Only a very small portion of the RDA for this complex can be supplied from sweet potatoes. An intense breeding effort could possibly double the concentration provided high concentration types are found for each of these vitamins. This would still supply only a small percentage of the RDA. It thus appears that an intense breeding effort in this area would be unwise.

This leaves two areas which we feel offer much potential for increase either through breeding or through cultural manipulation: vitamin C (ascorbic acid) and protein.

Vitamin C

Cultivars which are currently grown in the United States contain 11.4-12.5 mg/100g of ascorbic acid in the canned product, which supplies 25-28% of the RDA. In fresh tissue we have measured concentrations as high as 19 mg/100g (Table 2). Genotypes range from 0 mg/100g up to this value of 19 mg/100g (fresh weight basis). Although no breeding efforts have been undertaken to increase ascorbic acids content in this collection, it is conceivable to do so since variability exists between compatible types.

In addition, ascorbic acid content depends heavily on genotype, size, harvest date and curing/storage conditions (Junek and Sistrunk 1979). Vitamin C decreases with curing and storage, increases with late harvest, and is present in higher quantities in large roots and roots that have been baked.

Table 2. Evaluation of North Carolina breeding material for dry matter, percent protein (dry weight and fresh weight basis) and ascorbic acid

Genotype	% dry matter	protein (dry wt)	grotein (fresh wt)	Ascorbic acid (mg/100 gm fresh wt)
W-77	24	13.1	3.1	2.6
Rose Centennial	25	9.7	2.3	14.1
Leeland Bunch	22	9.4	2.1	10.5
Jewe 1	21	8.8	1.8	4.4
215	21	8.7	1.8	6.9
234	30	8.4	2.5	10.9
213 x 228-1	22	8.1	1.8	7.3
212	26	8.1	2.1	7.1
Redgo1d	22	8.0	¹ 1.8	4.7
Kandee	24	7.8	1.9	4.2
Centennial W-l	21	7.7	1.6	11.3
W-178	26	7.6	2.0	4.5
356	23	7.6	1.7	0.0
Nancy Hall	20	7.5	1.5	19.0
TI-1895	16	7.5	1.2	8.3
246	24	7.5	1.8	6.8
Painter	23	7.2	1.7	8.7
California Red	15	7.2	1.1	7.0
353	20	7.1	1.4	2.0
311(1)	23	7.0	1.6	16.2
lemago1d	20	7.0	1.4	9.8
old Goldrush	24	6.9	1.7	6.9
241 x 213	29	6.9	2.0	-
284	24	6.8	1.6	6.1
Hite Jewel	18	6.5	1.2	4.1
1 296116	20	6.4	1.3	1.7
273-0-42	23	6.2	1.4	7.6
arver	19	6.1	1.2	4.7
91 x 273-1	25	6.1	1.5	8.8
edcliff	22	5.9	1.3	4.2
89	30	5.9	1.8	14.8
oastal Sweet	34	5.8	2.0	5.6
aromex	21	5.6	1.2	-
I 1894	22	5.6	1.2	4.2
entennial	23	5.6	1.3	7.8
outhern Queen	23	5.5	1.3	17.4
-13	18	5.4	1.0	7.4
hite Star	23	5.4	1.2	4.8
elican Processor	20	4.7	0.9	5.9
11(2)	21	4.6	1.0	3.4
49	22	4.4	1.0	6.9
88	23	4.2	1.0	3.3
1 399163	24	4.0	1.0	0.0
1 1892	19	3.8	0.7	6.1
1 3441234	25	3.1	0.8	0.0

*

Protein

Protein is one of the most important chemical compounds involved in nutrition because of its involvement in so many of the basic processes and structures of the human body. Most people in the United States have an adequate intake of protein even if they are not meat or meat product eaters. Many vegetables contain adequate amounts of proteins.

However, there is now the distinct possibility that sweet potatoes will be used as a source of carbohydrate in the US for production of ethanol by microbial fermentation. Such a process would lead to highly concentrated sweet potato protein which would be available for incorporation into human food. In some parts of the world, sweet potatoes are consumed in large quantities and can be an important source of dietary protein; foods containing 5% utilizable balanced protein can sustain health if eaten in sufficient quantity. For these reasons, information on factors affecting crude protein in sweet potato plants as well as the quality and composition of that protein is important.

Several environmental factors have been shown to influence protein content in sweet potatoes. Purcell $\it et~al~(1976)$, studying length of growing season, determined protein and dry matter contents for 16 sweet potato genotypes harvested on four different dates. They found that protein content decreased at the rate of 0.0067% per day after 102 growing days with dry matter decreasing by 0.233% per day after 102 growing days. However early harvest, while maximizing % protein, would not offset the extra total protein obtained with later harvest because of increased yields.

Fertilization also affects crude protein in sweet potatoes. Purcell <code>et al</code> (unpublished) found that fertilizer had an effect on nitrogen content of the roots but did not change the non-protein N/N ratio (Table 3). An increase in the N content of the fertilizer caused a corresponding increase in N content in the harvested roots. Varying the amount of sulfur in the fertilizer had no effect on the composition of the roots. Apparently the soil used contained enough sulfur so that N uptake was not limited, or the ability to respond to sulfur fertilization does not occur in sweet potatoes as it does in some other crops (Rabufetti and Kamprath 1977). Potassium was also shown to have no effect on stored N in the root or on the NPN/N total ratio. These data suggest that the amount of protein in sweet potatoes could be increased by increasing N fertilizer; however, this would have to be managed very carefully since excess N at critical periods in the root enlargement phase of growth can decrease yields.

The effects of genotype on crude protein content are well described. Several studies have reported significant differences between genotypes (Purcell et at 1972; Edmond and Ammerman 1971). Table 2 shows protein content of North Carolina breeding materials in a 1980 survey evaluation. There are clearly differences between these genotypes which can be used in a breeding program to enhance protein content.

Crosses are underway now between high protein and high dry matter types in an effort to develop cultivars ideal for fuel alcohol production as well as cultivars for fresh market production with enhanced protein content. It appears that an important by-product, or perhaps even the most important product, of a sweet potato fuel alcohol operation will be a high protein con-

Table 3. Effect of N and S on total N and non-protein-N/N ratio of sweet potatoes (variety Jewel)

Treatment ^y	% Total N ²	NPN/N
N = 0, S = 0	0.78 a	0.25
N = 0, S = 71	0.82 a	0.24
N = 51, S = 0	1.04 b	0.24
N = 51, S = 71	0.92 ab	0.26
N = 101, S = 0	1.24 c	0.25
N = 101, S = 71	1.22 c	0.25

 y Figures with the same superscript are not significantly different at the 0.01 level using Duncan's New Multiple Range Test

²Treatments included 168 kg K/ha and 40 kg P/ha

Table 4. Dry matter, fermentation alcohol yield, and protein yield in fermentation residue of five sweet potato cultivars

Cultivar .	% dry matter	Alcohol yield (ml/kg)	% protein in residue	_
Centennial	25.9	94	30.1	
Pelican Processor	26.7	118	32.5	
Rojo Blanco	24.9	107	39.3	
Whitestar	26.4	113	33.6	
Vogel White	28.2	126	26.6	

centrate extracted from the residue. This concentrate is suitable for human consumption. Shown in Table 4 are five cultivars which we have so far studied in connection with alcohol yield. Although the dry matter in these cultivars is 10-15% less than some of the highest reported, the protein content in the residue is exceptionally high. Using higher dry matter types should increase this percentage even more.

The effect of genotype x environment interactions in sweet potato protein determinations was investigated in a study of six sweet potato genotypes grown at six locations for three years (eighteen environments). Protein content (reported on dry weight basis) varied tremendously during this period. The analysis of variance for this study is shown in Table 5.

Protein quality

Amino acid analyses of sweet potato protein are published. It has been shown by Purcell \it{et} \it{al} (1972) to be of good nutritional quality but marginal in lysine and deficient in total sulfur in comparison to FAO protein. It has also been shown to be deficient in tryptophan in terms of FAO standards

Table 5	· .			of	protein	genotype	X	environment
		interaction	study					

Source	d.f.	Significance
Genotype	5	**
Environment	71	**
Years	2	**
Locations	5	**
Years x Locations	10	**
Rep (Year x Loc)	54	**
Genotype x Environment	85	**
Year x Genotype	10	ns
Loc x Genotype	• 25	**
Year x Loc x Gen	50	**

**Significant at 1% level ns = not significant

although some cultivars contain more tryptophan than the FAO minimum (Splitt-stoesser and Martin 1975). However, no measure of the protein efficiency ratio (PER) of sweet potato has been reported until now.

Walter and Catigliani (1981) extracted white protein (protein isolate) and a grayish-white powder which is the protein concentrate or chromoplast protein from washed sweet potato roots of varieties Jewel and Centennial. The essential amino acid patterns for this chromoplast protein and for white protein are compared to FAO protein in Table 6. The total sulfur appears to be better in this protein than in white protein for Jewel. Lysine scores in the chromo protein of both cultivars were higher than in the white protein, and exceeded the FAO value.

The PER-using rats was measured to determine the biological quality of sweet potato protein. The PER is the weight gain of the rats divided by protein consumed (under standardized conditions as described by the AOAC). In addition the NPR (net protein ratio) was also determined. NPR corrects for body maintenance protein requirements. One group of rats is fed a noprotein diet and the weight loss of this group then can be used to credit the test protein for its maintenance function.

Results are shown in Table 7 for white protein and for chromoplast protein. For white protein, both cultivars appear to be slightly better than casein but not statistically better. There is about 135 g weight gain over the 28-day period for 47 g protein consumed. For chromoplast protein, the PER is closer to casein and is not quite as good numerically as the white protein; however, there are no statistically significant differences.

NPR values are shown in Table 8. They are better than PER values, of course, and the white sweet potato protein may be slightly better than casein which indicates that sweet potato protein is of high nutritional quality.

Table 6. Comparison of essential amino acid patterns for chromoplast and white protein in Jewel and Centennial sweet potato roots to FAO protein

	Chromo		FAO	White	
Amino acid ²	Jewe 1	Centennial	rau 	Jewe 1	Centennial
Threonine	5.77	5.67	4.0	6.43	6.39
Valine	7.83	7.68	5.0	7.90	7.89
Methionine (Total S)	2.26 (4.04)	2.10 (2.77)	(3.5)	2.03 (3.11)	1.84 (2.75)
Isoleucine	6.01	5.89	4.0	5.63	5.71
Leucine	9.64	8.95	7.0	7.40	7.44
Tyrosine	6.71	6.41	6.0	6.91	7.09
Phenylalanine	7.08	7.15		8.19	7.94
Lysine	7.03	6.43	5.5	5.16	5.21
Tryptophan	1.56	1.77	1.0	1.23	1.44

 $[^]z$ g amino acid/16 g N

Table 7. White and chromoplast protein of Jewel and Centennial sweet potatoes compared to casein in rat weight gain studies

	PER	Corrected PER	Weight gain (g)	Protein consumed (g)
	'CI	hromoplast' prote	ein	
Casein	2.73 ± 0.10	2.50 ± 0.09	109.5 ± 7.8	39.4 ± 2.53
Jewe1	2.75 ± 0.09	2.52 ± 0.09	117.6 ± 11.3	43.1 ± 3.95
Centennial	2.82 ± 0.10	2.58 ± 0.10	122.2 ± 14.9	43.8 ± 4.45
		'White' protei	n	
Casein	2.81 ± 0.11	2.50	134.3 ± 11.7	47.8 ± 3.8
Jewel	2.91 ± 0.10	2.63 ± 0.09	138.9 ± 11.7	47.7 ± 2.9
Centennial	2.96 ± 0.07	2.64 ± 0.07	140.3 ± 12.4	47.3 ± 3.5

Table 8. PER and NPR values of Jewel and Centennial sweet potatoes compared to casein

	PER	NPR
Casein	2.81	3.95
Jewel	2.91	4.15
Centennial	2.96	4.20

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SWEET POTATO

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